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Explorative randomized controlled study comparing soft tissue thickness, contour changes, and soft tissue handling of two ridge preservation techniques and spontaneous healing two months after tooth extraction

Thoma, Daniel S ; Bienz, Stefan P ; Lim, Hyun-Chang ; Lee, Wan Zhen ; Hämmerle, Christoph H F ; Jung, Ronald E

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Explorative randomized controlled study comparing soft tissue thickness, contour changes and soft tissue handling of two ridge preservation techniques and spontaneous healing two months after tooth extraction

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Key words: Alveolar ridge preservation, soft tissue healing, dental implant, early implant placement

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Abstract

Objectives: To compare two ridge preservation techniques and spontaneous healing in terms of soft tissue thickness, contour changes and soft tissue handling two months after tooth extraction.
Methods: Thirty-six patients were included with buccal bone plate dehiscences of up to 50% after single-tooth extraction in the esthetic zone. They were randomly assigned to receive one of three procedures: a deproteinized bovine bone mineral with 10% collagen (DBBM-C) covered with a collagen matrix (DBBM-C/CM), DBBM-C alone or spontaneous healing (SH). Two months later, the status of soft tissue healing was assessed, and the thickness of the mucosa was measured at the center of the site. Thereafter, implants were placed and the need for further guided bone regeneration (GBR) to cover exposed implant surfaces assessed.

Results: Thirty-six patients were evaluated at the day of implant placement. An invagination of the soft tissues was recorded in 41.7% (n=12), 53.8% (n=13) and 90.9% (n=11) of the sites in groups DBBM-C/CM, DBBM-C and SH respectively. The median thickness of the mucosa measured 3.0mm in group DBBM-C/CM, 2.1mm in group DBBM-C and 1.5mm in the SH group. Additional GBR was necessary in 66.7% (n=12), 53.8% (n=13) and 90.9% (n=11) of the sites in groups DBBM-C/CM, DBBM-C and SH respectively.

Conclusions: The present explorative study revealed slight tendencies for more favorable soft tissue conditions with less invaginations as well as increased soft tissue volume and thickness in groups having received an alveolar ridge preservation procedure compared to spontaneously healed sites at 8 weeks of healing.

Introduction

The physiological remodelling of both soft and hard tissues following tooth extraction has been examined in numerous pre-clinical and clinical studies (Amler, Johnson, Salman, 1960; Cardaropoli, Araujo, Lindhe, 2003; Fickl, Zuhr, Wachtel, Bolz, Huerzeler, 2008; Pietrokovski, Massler, 1967). A resorption of approximately 50% occurs mainly at the buccal area within the first 3 months (Schropp, Wenzel, Kostopoulos, Karring, 2003). Moreover, the extent of the horizontal reduction was found to be greater than the vertical one (Tan, Wong, Wong, Lang, 2012). Resorption of the soft and hard tissues may significantly hamper subsequent implant placement and may yield an inadequate esthetic outcome due to deficiencies in ridge dimensions (Grunder, 2000).

Methods to attenuate the effects of the physiological resorption included bone substitute materials with and without barrier membranes or soft tissue coverage (Araujo, da Silva, de Mendonca, Lindhe, 2015; Araujo, Sukekava, Wennstrom, Lindhe, 2005; Barone, et al., 2008; Fickl, et al., 2017; Iasella, et al., 2003; Jung, et al., 2013; Vignoletti, et al., 2012). A recent systematic review concluded that while alveolar ridge preservation (ARP) therapies were effective in reducing the post-extraction dimensional ridge resorption, none of the interventions were able to completely preserve the ridge dimensions (Avila-Ortiz, Chambrone, Vignoletti, 2019). Multiple materials are available for hard and soft tissue regeneration or preservation and numerous combinations thereof have been studied. Deproteinized bovine bone mineral with 10% collagen (DBBM-C) is one of the best documented bone substitute materials used. This material is often combined with an autogenous soft tissue graft, barrier membranes or a collagen matrix (CM) to close the entrance to the socket (Cardaropoli, Tamagnone, Roffredo, Gaveglio, Cardaropoli, 2012; Jung, et al., 2013; Nart, et al., 2017). So far, no study compared DBBM-C alone versus DBBM-C covered by a collagen matrix.

A major drawback of ARP procedures is the increased healing period necessary to obtain a sufficient amount of bone formation compared to early or immediate implant placement protocols. The documented healing times summarized in a recent systematic review ranged from 3 to 6 months,

with the majority of the studies reporting healing times of more than 4 months. Furthermore, no studies analyzed the effect of ARP on soft tissue thickness and maturity (Avila-Ortiz, et al., 2019). Earlier studies have indicated that the use of a collagen matrix can accelerate early soft tissue healing (Thoma, Sancho-Puchades, Ettlin, Hammerle, Jung, 2012) and might also increase soft tissue thickness.

Early implant placement protocols rely on completed soft tissue healing (Buser, et al., 2009). Whether ARP procedures could potentially improve the soft tissue conditions at 8 weeks is currently not investigated. A previous preclinical study demonstrated that the concept of ARP and early implant placement resulted in similar contour changes compared to spontaneous healing and subsequent implant placement with GBR (Thoma, et al., 2017).

Therefore, the aim of this randomized clinical study was to compare two ridge preservation techniques and spontaneous healing in terms of soft tissue thickness, contour changes and soft tissue handling two months after tooth extraction.

Material and Methods

This study was designed as an explorative randomized controlled clinical study according to the Helsinki protocol with two treatment groups and a negative control group. At present no scientific data exist on using ARP with an end-point of 2 months and a focus on soft tissue healing, therefore a priori power calculation was not conducted. The present study was approved by the local ethical committee No. 2015-0420 (new: PB_2016-02507) and registered in the German Register of Clinical Trials (DRKS00009496).

Study population

This prospective study recruited patients presenting at the Clinic of Reconstructive Dentistry requiring single-tooth extractions and subsequent implant placement. They were consecutively recruited between November 2015 and June 2018. Surgeries were performed by more than one clinician. However, all surgeons were calibrated and surgeries were supervised by the main (DTH) and/or co-investigator (SBI). Teeth eligible for the study included fractures, chronic apical periodontitis or root resorption of dental or traumatic origin in the absence of suppuration or acute inflammation. Molar sites were excluded and at least one neighboring tooth needed to be available. Systemically healthy patients aged between 18 – 80 years were included. The exclusion criteria at the time of patient recruitment were smoking more than 20 cigarettes per day, poor oral hygiene (plaque index >20%), untreated periodontitis or pregnancy.

Tooth extraction and ridge preservation/spontaneous healing

Following the screening visit, patients were scheduled for tooth extraction. A partial sectional A-silicone impression (President, Coltène Whaledent, Alstätten, Switzerland) of the tooth planned for extraction was taken. The site was anesthetized (Ultracain® D-S, Hoechst-Pharma AG, Zurich, Switzerland) and care was taken to avoid damage to the buccal bone plate and the surrounding soft and hard tissues during tooth extraction. Thereafter, the granulation tissue was carefully removed with hand instruments and the socket was rinsed with sterile saline. The socket was then examined and the height of the buccal and oral bone plates were measured with a periodontal

probe. Patients were withdrawn from the study if more than 50% of the height of the buccal bone plate was missing. At this time point, a sealed envelope was opened containing the following group allocation according to a computer-generated list (n = 10 per group):

- **DBBM-C/CM:** DBBM-C (deproteinized bovine bone mineral with 10% collagen, Bio-Oss® Collagen, Geistlich Pharma AG, Wolhusen, Switzerland) was placed within or slightly higher than the palatal bone plate in order to ideally support the collagen matrix to be placed. Subsequently, the soft tissue borders were de-epithelialized using a diamond drill under copious irrigation with water. A collagen matrix (CM; Mucograft® Seal, Geistlich Pharma AG) with a dimension of 8 mm diameter was pre-cut and adapted and sutured to the soft tissue borders using single interrupted sutures (Dafilon No. 6/0, Braun Aesculap, Germany) (Figure 1).
- **DBBM-C:** DBBM-C was placed as described above and a criss-cross suture was used to stabilize the bone substitute material without the intention to obtain primary wound closure (Figure 1).
- **Spontaneous healing (SH):** No further treatment was applied and the coagulum within the socket was left for spontaneous healing, without placement of a suture (Figure 1).

A second impression, as described above, was taken after the treatment was completed. Postoperatively, patients were instructed to rinse twice daily with a solution containing 0.2% chlorhexidine (Kantonsapotheke Zürich, Zürich, Switzerland) for 7 days. The patients also received analgesics (Mefenacid, Streuli Pharma, Uznach, Switzerland) and the two test groups received 750mg of amoxicilline three times per day for 5 days (Amoxicillin Sandoz, Sandoz, Basel, Switzerland). All patients were recalled at 7-10 days for a clinical examination and suture removal (treatment groups only). Subsequently, patients followed an individualized maintenance program according to their periodontal and caries risk assessments.

Implant placement

Two months after tooth extraction, implants were placed in all sites according to the early (Type 2) implant placement protocol (Hammerle, Chen, Wilson, 2004). On the day of implant placement, a third impression was taken and the crestal soft tissue status was evaluated clinically. Following anesthesia (Ultracain® D-S), a mucoperiosteal flap was raised, with a single vertical releasing incision when necessary. The thickness of the mucosa was measured at the center of the future implant position using a caliper. Loose DBBM granules remaining from the ridge preservation procedure were removed carefully. Subsequently, the implants were placed. In cases of dehiscence or fenestration defects, or thin buccal bone plates (< 1.5mm, measured between the implant shoulder and the buccal bone horizontally) a guided bone regeneration procedure (GBR) was performed. DBBM (deproteinized bovine bone mineral; Bio-Oss®, Geistlich Pharma AG) granules and/or DBBM with 10 % Collagen (Bio-Oss® Collagen, Geistlich Pharma AG) in combination with a native collagen membrane (Bio-Gide®, Geistlich Pharma AG) optionally fixed with resorbable pins when needed (LeadFIX, ImperiOs, Bad Homburg, Germany) were used. Subsequently, a periosteal releasing incision was performed in order to achieve tension-free primary wound closure. Horizontal mattress sutures (Gore-tex® 5/0, W.L. Gore & Associates, Flagstaff, AZ, USA) and single interrupted sutures (Dafilon No. 5/0, Braun Aesculap) were placed to secure the flap in position. In the absence of GBR, transmucosal or submerged healing were possible. Postoperatively, patients followed the same protocol as after extraction, receiving rinsing solutions, analgesics and antibiotics when GBR was performed.

Measurements (chronological order):

- Presence of a dehiscence of the buccal bone plate after tooth extraction.
- Clinical condition of the soft tissues at two months (healed or invaginated surface). Healed sites presented a smooth texture, evenly keratinized and absence of color differences. Any concavities in the crestal area were considered as invagination (*Amler, 1969*).
- Thickness of the mucosa (primary outcome) measured at the center of the future implant position using a caliper. Not-yet mineralized tissue inside the underlying socket was not taken into consideration for this measurement.

- Type of bone defect after implant placement and need for GBR at implant placement.
- Difficulty in the handling of the soft tissues during flap elevation and wound closure assessed using a visual analogue scale (VAS) ranging from 1 (very difficult) to 10 (easy). Blinding of the treatment was not possible.
- Profilometric measurements: Dental casts were fabricated from the silicon impressions taken prior to and after tooth extraction and prior to flap elevation at two months. The casts were digitized with a scanner (Imetric 3D, Courgenay, Switzerland) and the STL files obtained (standard tessellation language) were imported into a digital imaging software program (SMOP, Swissmeda AG, Zürich, Switzerland). The STL files were superimposed manually for best fit using neighboring teeth as reference structures. A region of interest (ROI) was selected on the baseline scan with a mesio-distal extension corresponding to the width of the tooth. The apico-coronal dimension was defined by a coronal border 1mm below the gingival margin and an apical extension of 3 mm but not surpassing the mucogingival junction. The software then calculated the mean distance (MD, mm) between the surfaces of the two scans within the ROI (Figure 2a). Subsequently, a bucco-oral cross-section was selected dividing the area of interest into two equal parts. A reference line was drawn through the buccal and oral gingival margin on the baseline STL. Horizontal ridge width (HW) was measured on all three STLs 3mm and 5mm below the reference line (HW3, HW5) and the changes over time were expressed in percentages. The vertical change in the center of the ridge was measured perpendicularly to the reference line and also expressed as percentage (Figure 2b). All measurements were done by one calibrated examiner.
- A wound healing index (Score 0-5) based on the photographs taken at two months was performed by two blinded and calibrated examiners assessing color, contour and invagination (Table 1).

Statistical analysis

Data were computed in Excel (Microsoft Corp., Redmond, WA, USA). Mean, median, standard deviation, quartiles and range were used to describe continuous variables, counts and percentages were used for categorical variables. In addition, differences of means, concomitant 95% confidence intervals and absolute effect sizes were calculated. Effect sizes were considered to be small (<0.5), moderate (0.5-0.8) and large (>0.8) (Cohen, 1988). Thickness of the mucosa at two months after tooth extraction was determined as the primary outcome.

Results

A total of 46 patients were screened. Seven patients were excluded because of a buccal bone plate dehiscence exceeding 50% at the time of tooth extraction. In 3 patients, implant placement was not feasible at two months. One patient (DBBM-C) postponed the implant placement and was therefore excluded. Another patient (SH) could not undergo implant surgery anymore due to medical conditions. In one patient (DBBM-C/CM) implant placement was not feasible at 8 weeks as judged by the surgeons based on the preoperative radiograph. It was assumed that primary stability would have been difficult to achieve as there was a low amount of bone around the healing extraction socket.

Thirty-six patients were successfully treated; 12 in group DBBM-C/CM, 13 in group DBBM-C, and 11 in group SH. The median age of the patients was 67.0 years, 50.0% of the patients were women and 16.7% (n=36) were smokers (less than 20 cigarettes per day). Seventy-five percent of all teeth were located in the maxilla. Twenty premolars, 22 incisors and 4 canines were included (Table 2). At the time of extraction, a bony dehiscence was present in 33.3% (n=12) and 38.5% (n=13) of the sites in groups DBBM-C/CM and DBBM-C respectively, while only 18.2% (n=11) of the sites had a dehiscence in the SH group. During the healing phase of two months after tooth extraction, no complications were recorded in 35 patients. In all these patients, implants could be placed with primary stability (implant was in a stable position, no spinner, no torque measurements performed, however). In one patient in group DBBM-C, pus was present at two months. It was decided to proceed with implant placement according to the study protocol. After flap elevation, the area was cleaned meticulously, and any loose biomaterial particles were removed. Subsequently, the implant was placed with primary stability. In all groups, in case of dehiscence or fenestration defects or a thin buccal bone, a GBR procedure was performed.

Assessment of soft tissues

At the time of implant placement, an invagination of the soft tissues was recorded in 41.7% (n=12), 53.8% (n=13) and 90.9% (n=11) of the sites in groups DBBM-C/CM, DBBM-C and SH respectively. The median thickness of the mucosa measured 3.0mm (first quartile (Q1) = 2.2;

third quartile (Q3) = 3.0) in group DBBM-C/CM, 2.1mm (Q1 = 1.5; Q3 = 3.0) in group DBBM-C and 1.5mm (Q1 = 0.6; Q3 = 2.2) in the SH group (Figure 3). A negligible effect was reported for DBBM-C/CM – DBBM-C (0.0), while moderate effects were found for DBBM-C/CM – SH (0.6) and for DBBM-C – SH (0.6).

The VAS for the handling of the flap was 9.0 (Q1 = 7.5; Q3 = 9.0) in group DBBM-C/CM, 7.0 (Q1 = 6.0; Q3 = 9.0) in group DBBM-C and 7.5 (Q1 = 7.0; Q3 = 9.0) in the SH group. The effect size was moderate for DBBM-C/CM – DBBM-C (0.7) and small for DBBM-C/CM – SH (0.4) and DBBM-C – SH (0.3). The VAS for wound closure amounted to 9.0 (Q1 = 7.0; Q3 = 9.0) in group DBBM-C/CM, 8.0 (Q1 = 6.0; Q3 = 9.0) in group DBBM-C and 8.5 (Q1 = 7.0; Q3 = 9.0) in the SH group. Small effect sizes were found for all comparisons; DBBM-C/CM – DBBM-C (0.3), DBBM-C – SH (0.3), DBBM-C/CM –SH (0.1).

The mean score according to the wound healing index (Score 0-5) amounted to 1.75 in group DBBM-C/CM, 1.67 in group DBBM-C and 0.55 in the SH group.

Profilometric contour changes

The median contour changes between pre-extraction and post-extraction (after ARP or SH) amounted to -0.2mm (Q1 = -0.3; Q3 = -0.1), -0.3mm (Q1 = -0.6; Q3 = -0.1) and -0.2mm (Q1 = -0.3; Q3 = -0.1) in groups DBBM-C/CM, DBBM-C and SH. The median changes between pre-extraction and pre-implant placement were -1.2mm (Q1 = -1.8; Q3 = -0.8) in group DBBM-C/CM, -1.6mm (Q1 = -1.8; Q3 = -1.0) in group DBBM-C and -1.5mm (Q1 = -2.4; Q3 = -1.2) in the SH group. The respective effect size was negligible for DBBM-C/CM – DBBM-C (0.0), but moderate for DBBM-C/CM – SH (0.7) and for DBBM-C – SH (0.7).

The linear changes (horizontally and vertically) are presented in table 3. The median reduction in ridge width up to two months ranged between 14.3% and 21.0% at HW3 and between 6.5% and 8.1% at HW5 for all groups. All profilometric changes are presented in table 3 and concomitant confidence intervals and effect sizes are summarized in table 4.

Need for GBR

The type of bone defect is summarized in table 2. At implant placement, additional GBR was necessary in 66.7% (n=12), 53.8% (n=13) and 90.9% (n=11) of the sites in groups DBBM-C/CM, DBBM-C and SH respectively. Seven out of eleven sites (63.3%) presenting a dehiscence of the buccal bone plate at tooth extraction needed GBR at implant placement. Sites presenting an intact buccal bone at tooth extraction but nevertheless requiring a GBR procedure at implant placement were distributed as follows: 5 in DBBM-C/CM, 4 in group DBBM-C, and 9 in group SH.

Discussion

The present explorative randomized controlled clinical trial revealed i) a tendency for improved soft tissue volume and less invaginations for ARP procedures compared to spontaneous healing, ii) a trend favoring the placement of collagen matrix for all measured soft tissue outcomes and, iii) a more frequent need for GBR at implant placement in group spontaneous healing.

An important prerequisite for successful wound healing in oral surgery is a well matured, thick soft tissue facilitating flap elevation and adaptation (Burkhardt, Lang, 2015). An increased soft tissue thickness leads to a larger area of tissue adaption during primary wound closure, ultimately resulting in a lower rate of wound dehiscences (Burkhardt, Lang, 2010). The present study revealed more than 90% of the sites with spontaneous healing presenting with invagination 2 months after tooth extraction. It should also be considered that the present report excluded the most severe sites with impaired healing conditions (with a loss of more than 50% of the buccal plate, in 7 out of 46 patients). The high rate of invaginations in the spontaneous healing group led to lower VAS scores in terms of ease of flap elevation and suturing compared to the ARP groups. The overall numbers demonstrate that there is room for improvement in terms of soft tissue healing in order to facilitate implant surgery at any time-point, irrespective of the aim of a hard tissue regeneration. The median thickness of the mucosa amounted to 3mm in group DBBM-C/CM compared to 1.5mm in group SH, underlined by a moderate effect size. Another study reported increased soft tissue thickness using DBBM-C in combination with CM or with an autologous punch graft over 6 months (Jung, et al., 2013). However, these data are based on CBCT measurements, providing evidence for an overall improved healing, but not directly referring to the soft tissue thickness. A further study evaluated the soft tissue thickness at extraction and at two months by means of CBCT, but only following spontaneous healing (Chappuis, et al., 2015). Focusing on their vertical measurements, thin and thick bone phenotypes lost between 1.5mm and 2mm of soft tissue vertically in a similar area of measurement. Considering that the soft tissue thickness i.e. the biological width around the tooth amounts to 3mm, these findings are in line with the present study. One can conclude that DBBM-C/CM was able to preserve the vertical soft tissue thickness,

while SH lost up to 50% of thickness. However, healing is still ongoing and further changes will occur up to 6 months, meaning that the complete effect of the treatment is not visible at 8 weeks.

Even though the clinicians reported a high number of invaginations, the rate was even higher when assessed on photographs by the wound healing index. It was suspected that the clinicians rather rated according to whether the soft tissue status would affect their incision design or the suturing. The index strictly evaluated if there was an invagination present or not. Overall, the scores of the index were low with values amounting to a range between 0.55 and 1.75, considering this was a five-point scoring system. Still, DBBM-C/CM reached a three times higher score compared to SH, mainly due to differences in terms of contour and invagination rating.

The contour changes documented a buccal collapse of 0.2mm to 0.3mm simply by performing tooth extraction. This loss could not be prevented with the placement of the grafting material. Alveolar ridge preservation has been documented to preserve 80-90% of the overall volume (Cardaropoli, Tamagnone, Roffredo, De Maria, Gaveglio, 2018). On top of the biological processes, the described initial collapse is one of the reasons why a flapless technique cannot reach a complete preservation of the tissue volume (Lee, Lee, Koo, Seol, Lee, 2018). Considering the shorter healing period in the present trial, the reduction of 1.2mm to 1.6mm is well in line with other data (Schneider, et al., 2014). More pronounced differences could be expected after longer observation periods due to ongoing healing processes. Still, the moderate effect sizes indicate a difference compared to spontaneous healing, while there was no obvious difference between the ridge preservation groups.

In the present study ARP reduced the need for GBR procedures at two months compared to the control group. The need for further augmentation at the time of implant placement after ARP compared to spontaneous healing has been reported in almost a dozen studies. However, due to several confounding factors (implant size and angulation, surgical protocol, location) there is still no conclusive statement possible whether ARP can reduce the number of GBR procedures at implant placement (Mardas, Trullenque-Eriksson, MacBeth, Petrie, Donos, 2015). One could

speculate that ARP is simpler to execute than a GBR procedure. A flapless ARP procedure at tooth extraction might not affect patient morbidity as much as a GBR procedure at implant placement. GBR in the ARP groups was often necessary because the placed bone substitute was soft at two months and was removed after flap elevation upon the surgeon's decision. Clinically, it remains difficult to judge whether the soft material, which is in a state of an ongoing healing process, will eventually turn into bone. A preclinical study (Thoma, et al., 2017) compared sites having received ARP. The soft material was either left in situ or removed and replaced with a GBR procedure. Osseointegration was not affected and first bone-to-implant contact did not differ between the groups.

The main limitation of the study was the sample size. Due to the evaluation of a different time-point and different outcomes compared to existing literature (Avila-Ortiz, et al., 2019), a suitable power calculation could not be performed. The number of patients in the present study, however, was similar to another study implementing comparable interventions (Jung, et al., 2013). Furthermore, a certain variance within that small sample size may exist regarding the extraction sockets. There have been patients included with a history of periodontitis exhibiting reduced bone levels. However, the presence of a dehiscence was evaluated as a percentage. However, weak trends are consistent among all evaluated outcomes, indicating optimized soft tissue thickness, minimized contour changes and improved soft tissue handling of with DBBM-C/CM over DBBM-C over SH. Another limitation was the distribution of antibiotics to ARP groups only, which was clinically reasonable, but remains as a confounder in the study. Considering the limitations mentioned, ARP was able to improve soft tissue volume and the number of invaginations at two months. Associated with this finding was an improved flap elevation and adaption reported by the surgeons.

Conclusions

The present explorative study revealed slight tendencies for more favorable soft tissue conditions with less invaginations as well as increased soft tissue volume and thickness in groups having received an alveolar ridge preservation procedure compared to spontaneously healed sites at 8 weeks of healing. The additional placement of a collagen matrix appeared to result in more favorable outcomes across all measured parameters. In addition, GBR was more frequently needed in spontaneously healed sites.

Figure Legend

Figure 1 The first row represents the treatment of a patient in group DBBM-C/CM, the second row one treated with DBBM-C, and the third row a case with spontaneous healing. The column of pictures (from left) represents the clinical situation right after tooth extraction, after the alveolar ridge preservation procedure, at suture removal, at two months of healing, after flap elevation and right after implant placement.

Figure 2a Selected region of interest for the profilometric measurement (red). The pre-extraction STL file (yellow) was superimposed with the post-extraction (green) and 2-month STL file (grey).

Figure 2b Cross-sectional view of the same site, the profilometric measurement is marked red again. A reference line (Ref, white) was drawn through the buccal and oral gingival margin of the baseline STL (yellow). Horizontal ridge width was measured (orange) on all three STLs at 3mm and 5mm below the reference line (HW3, HW5). The vertical change in the center of the ridge was measured, perpendicularly to the reference line (blue).

Figure 3 Scatterplot diagram depicting the thickness of the mucosa at two months. The horizontal lines represent the medians.

Table 1 Wound healing index applied on the clinical photographs taken at two months prior to anesthesia and flap elevation.

Table 2 Patient characteristics including gender, age, smoking status, site and neighboring teeth. DBBM-C = deproteinized bovine bone mineral with 10% collagen; DBBM-C/CM = deproteinized bovine bone mineral with 10% collagen covered with a collagen matrix; SH = spontaneous healing.

Table 3 The soft tissue changes reported for each group between pre- and post-extraction as well as between pre-extraction and pre-implant placement (two months). (-) denotates reduction/loss. DBBM-C = deproteinized bovine bone mineral with 10% collagen; DBBM-C/CM = deproteinized bovine bone mineral with 10% collagen covered with a collagen matrix; SH = spontaneous healing; HW = horizontal width at 3 and 5 mm below the reference line; n = number; SD = standard deviation; Min = minimum; Q1 = first quartile; Q3 = third quartile; Max = maximum.

Table 4 Summary of the differences of means with the respective confidence interval and absolute effect sizes. DBBM-C = deproteinized bovine bone mineral with 10% collagen; DBBM-C/CM = deproteinized bovine bone mineral with 10% collagen covered with a collagen matrix; SH = spontaneous healing; CI = confidence interval; VAS = visual analogue scale

Conflict of interest

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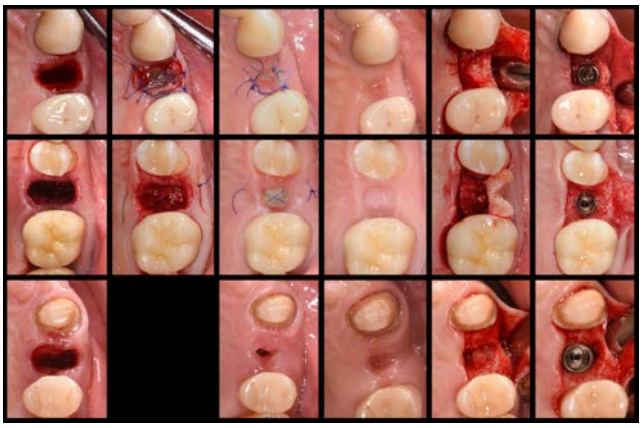

Figure 1

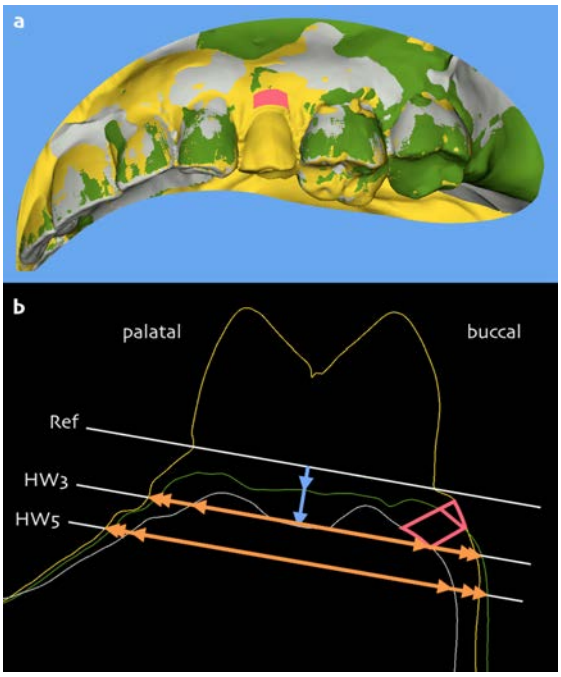

Figure 2

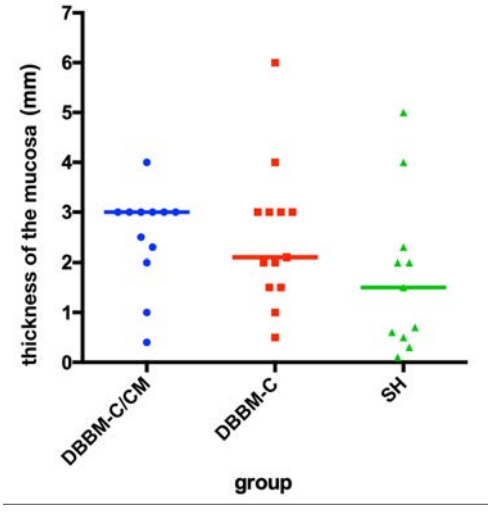

Figure 3

Soft tissue characteristics	Criteria	Score
Color	Same as neighboring tissue	1
	Different from neighboring tissue	0
Size of Invagination	Absent	2
	0 – 2 mm (at the widest point)	1
	> 2 mm (at the widest point)	0
Contour	No loss of buccal contour	2
	Loss of buccal contour ≤ 1mm from a line joining the most convex point at the cervical location of the adjacent teeth (occlusally)	1
	Loss of buccal contour (as above) >1mm	0

Table 1

		DBBM-C/CM	DBBM-C	SH	Total
Number		12	13	11	36
Gender	Male	7 (58.3%)	8 (61.5%)	3 (27.3%)	18 (50.0%)
	Female	5 (41.7%)	5 (38.5%)	8 (72.7%)	18 (50.0%)
Age	Median	66.5	71.0	64.0	67.0
	Q1; Q3	53.0; 71.5	55.0; 74.0	52.0; 71.0	55.0; 72.0
Smokers, <10 cigarettes per day		1 (8.3%)	0 (0%)	0 (0%)	1 (2.8%)
Smokers, 10-20 cigarettes per day		0 (0%)	2 (15.4%)	3 (27.3%)	5 (13.9%)
Maxillary	Incisors	4	1	5	10
	Canines	1	1	1	3
	Premolars	4	7	3	14
Mandibular	Incisors	0	2	0	2
	Canines	0	1	0	1
	Premolars	3	1	2	6
One neighboring tooth		2 (16.7%)	6 (46.2%)	6 (54.5%)	14 (38.9%)
Two neighboring teeth		10 (83.3%)	7 (53.8%)	5 (45.5%)	22 (61.1%)
Buccal bone dehiscence of 0-50% right after extraction		4 (33.3%)	5 (38.5%)	2 (18.2%)	11 (30.6%)
Thin buccal bone (<1.5mm) after implant placement		3 (25%)	0 (0%)	1 (9.1%)	4 (11.1%)
Dehiscence defect type after implant placement		3 (25%)	5 (38.5%)	5 (45.5%)	13 (36.1%)
Fenestration defect type after implant placement		0 (0%)	0 (0%)	2 (18.2%)	2 (5.6%)
Intrabony defect type after implant placement		1 (8.3%)	1 (7.7%)	1 (9.1%)	3 (8.3%)
Guided bone regeneration after implant placement		8 (66.7%)	7 (53.8%)	10 (90.9%)	25 (69.4%

Table 2

		Group	n	Mean	SD	Min	Q1	Median	Q3	Max
Change between pre- and post- extraction	**Mean Distance (mm)**	DBBM-C/CM	11	-0.2	0.3	0.4	-0.1	-0.2	-0.3	-0.5
		DBBM-C	13	-0.3	0.3	0.1	-0.1	-0.3	-0.6	-0.8
		SH	11	-0.3	0.4	0.2	-0.1	-0.2	-0.3	-1.2
	HW 3 (mm)	DBBM-C/CM	11	0.2	0.5	-0.3	-0.1	0.0	0.1	1.6
		DBBM-C	13	0.0	0.4	-0.6	0.1	0.0	-0.2	0.9
		SH	10	0.0	0.4	0.7	0.0	0.0	-0.2	-0.8
	HW 3 (%)	DBBM-C/CM	11	1.5	4.6	-2.3	-0.3	0.0	1.1	15.4
		DBBM-C	13	0.5	3.3	-4.8	1.0	0.0	-1.2	7.6
		SH	10	-0.2	2.7	4.2	0.0	0.0	-1.5	-5.3
	HW 5 (mm)	DBBM-C/CM	10	0.3	0.5	0.0	0.0	0.1	0.2	1.5
		DBBM-C	8	0.3	0.5	-0.4	0.0	0.2	0.4	1.4
		SH	6	0.1	0.3	-0.1	0.0	0.0	0.1	0.6
	HW 5 (%)	DBBM-C/CM	10	2.3	3.9	-0.2	0.1	1.0	1.5	13.3
		DBBM-C	8	2.1	3.7	-2.9	0.0	1.5	2.8	10.7
		SH	6	0.6	1.5	-0.6	0.0	0.0	0.3	3.8
Change between pre- extraction and pre-implant placement	**Mean Distance (mm)**	DBBM-C/CM	12	-1.3	0.7	0.0	-0.8	-1.2	-1.8	-2.6
		DBBM-C	13	-1.3	0.6	0.2	-1.0	-1.6	-1.8	-2.0
		SH	11	-1.8	0.8	-0.8	-1.2	-1.5	-2.4	-3.6
	HW 3 (mm)	DBBM-C/CM	12	-2.0	1.5	0.0	-1.3	-1.7	-2.6	-5.9
		DBBM-C	12	-1.8	1.0	-0.1	-1.1	-1.9	-2.4	-3.4
		SH	10	-2.5	1.0	-1.4	-1.6	-2.5	-2.6	-4.7
	HW 3 (%)	DBBM-C/CM	12	-18.3	14.5	0.0	-10.8	-14.3	-22.3	-55.6
		DBBM-C	12	-15.9	8.5	-1.5	-9.8	-15.1	-22.6	-28.5
		SH	10	-21.5	9.2	-13.0	-13.5	-21.0	-24.7	-44.5
	HW 5 (mm)	DBBM-C/CM	11	-1.1	0.9	0.0	-0.4	-1.1	-1.5	-3.1
		DBBM-C	9	-1.0	0.6	0.0	-0.7	-1.0	-1.2	-2.2
		SH	7	-1.2	0.9	-0.5	-0.6	-0.8	-1.5	-3.0
	HW 5 (%)	DBBM-C/CM	11	-9.3	7.5	0.0	-4.1	-8.1	-13.6	-26.8
		DBBM-C	9	-7.7	4.8	0.0	-5.0	-6.5	-11.4	-17.4
		SH	7	-9.6	7.6	-3.5	-4.2	-7.4	-10.6	-26.9
	Vertical Change (mm)	DBBM-C/CM	12	-1.2	0.7	0.0	-0.7	-1.0	-1.9	-2.1
		DBBM-C	13	-1.2	0.8	0.5	-0.8	-1.5	-1.9	-2.4
		SH	11	-1.8	1.0	-0.6	-1.2	-1.5	-2.2	-4.4

Table 3

	Group	Difference of Means	Lower 95% CI	Higher 95% CI	Effect size
Mucosa thickness (mm)	DBBM-C/CM - DBBM-C	0.0	-1.1	1.1	0.0
	DBBM-C/CM- SH	0.8	-0.4	1.9	0.6
	DBBM-C - SH	0.8	-0.3	1.9	0.6
VAS flap handling (score 0-10)	DBBM-C/CM - DBBM-C	1.6	-0.3	3.4	0.7
	DBBM-C/CM- SH	1.0	-1.0	2.9	0.4
	DBBM-C - SH	-0.6	-2.5	1.4	0.3
VAS wound closure (score0-10)	DBBM-C/CM - DBBM-C	0.7	-1.1	2.5	0.3
	DBBM-C/CM- SH	-0.2	-2.1	1.7	0.1
	DBBM-C - SH	-0.9	-2.7	1.0	0.4
Mean Distance between pre- and post- extraction (mm)	DBBM-C/CM - DBBM-C	0.2	-0.1	0.4	0.5
	DBBM-C/CM- SH	0.1	-0.2	0.4	0.3
	DBBM-C - SH	-0.1	-0.3	0.2	0.2
Mean Distance between pre- extraction and 8 weeks (mm)	DBBM-C/CM - DBBM-C	0.0	-0.6	0.6	0.0
	DBBM-C/CM- SH	0.5	-0.1	1.2	0.7
	DBBM-C - SH	0.5	-0.1	1.1	0.7
Vertical change (mm)	DBBM-C/CM - DBBM-C	0.1	-0.7	0.8	0.1
	DBBM-C/CM- SH	0.6	-0.1	1.4	0.7
	DBBM-C - SH	0.6	-0.2	1.3	0.7

Table 4